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### Textural Stresses in Metals *Measured by X-ray*

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DETROIT

**I**N RECENT EXPERIMENTS at the National Bureau of Standards, textural stresses in metals have been measured by X-ray. Results of the experiments show the impossibility of obtaining a completely stress-free condition in metals which contain more than one phase. Consequently, textural stresses must be considered in investigations to determine the cause of corrosion, metal fatigue, and crack formations in metals used for industrial purposes. The data derived from this work should aid metallurgists in relating internal stresses to the mechanical and physical properties and behavior of two-phase alloys.<sup>1</sup>

Metals usually consist of many microscopic grains or crystals. If the metal is an alloy, it is very common for more than one phase to be present; that is, all of the crystalline grains may not be alike. For example, in a solidified alloy prepared by mixing unequal parts of copper and zinc together in the molten state, there are two different grains present. The grains are neither copper nor zinc but two phases of brass. One phase is alpha brass and the other, beta brass, both present in approximately equal quantities. Each phase has its own crystal structure and physical properties.

Among the properties of two-phase alloys which differ are the thermal expansion coefficients of the two phases. As a result, there is a tendency toward unequal changes in the volume of each phase as the metal cools from the liquid state. The unequal volume changes cause intergranular forces to arise which are known

as textural stresses. These stresses are to be distinguished from the other type of internal stress occurring in metals known as body stresses, both of which have been thoroughly reviewed in the literature under several systems of nomenclature.<sup>2</sup>

In conducting the experiments, Clarence J. Newton and Herbert C. Vacher of the mechanical metallurgy laboratory used annealed specimens of brasses and of carbon steel. Formulas for the approximate values of the principal stresses in the grains were obtained from a detailed theoretical analysis of textural stresses made by F. László.<sup>3</sup> To avoid extraneous stresses, the surfaces of the metal specimens were carefully finished with many cycles of alternate mechanical polishing and electropolishing.

Stress measurements were made by X-ray diffraction techniques which permit highly precise determination of the interatomic distances in crystals. When a stress arises, a regular change occurs in the spacing of the atoms, and as the X-ray diffraction "sorts out" the separate phases, it is possible to measure these microscopic stresses if they affect one phase differently from another. An averaging of the triaxial stress state over many grains of one phase results in a pseudo-hydrostatic stress. However, relaxation of the component normal to the exposed free surface results in a biaxial state of stress whose average value can be measured by the well-known two-exposure X-ray method.<sup>4</sup>

The observed relative lattice changes and the calculated values of the stresses for the brass specimens are presented in table 1. This table also shows the probable error in the stress measurement and the theoretical values of stress calculated for the two-phase brass. Table 2 gives the calculated values of the stresses for the steel specimens. The stresses observed ranged from  $-5,270 \text{ lb/in.}^2$  to  $+14,380 \text{ lb/in.}^2$ . The probable error in measurement in most of the experiments was

TABLE 1. Stresses in brass

Specimen	Alpha brass		Beta brass	
	Strain	Stress	Strain	Stress
Two-phase	$-2.58 \times 10^{-4}$	$\text{lb/in.}^2$ $-5.27 \times 10^3$	$4.47 \times 10^{-4}$	$\text{lb/in.}^2$ $6.53 \times 10^3$
Single-phase	$-1.39$	$-2.83$		
Theoretical values of stress				
Two-phase		$-4.33$		$5.33$

Precision in experimental stress about  $\pm 3.2 \times 10^3 \text{ lb/in.}^2$

about  $3,000 \text{ lb/in.}^2$ . The measured values of the brass specimens agreed very well with the theoretical values of László, and those of the steel agreed to a qualitative degree.

This work experimentally validates László's theoretical analysis of textural stresses arising from inequalities of thermal expansion of microconstituents. Also, the success of the experiments contradicts previously expressed opinion that such stresses could not be measured by X-ray. The only caution that must be observed is careful surface preparation of the metal specimens to avoid extraneous results in the X-ray diffraction.

<sup>1</sup> For further details, see An X-ray study of textural stresses in two-phase alloys, by C. J. Newton and H. C. Vacher, *J. Research NBS* **59**, 239 (1957) RP2793.

<sup>2</sup> Classification and nomenclature of internal stresses, by E. Orowan, *Symposium on internal stresses in metals and alloys, Institute of Metals Monograph and Report Series, No. 5*, 47 (1948).

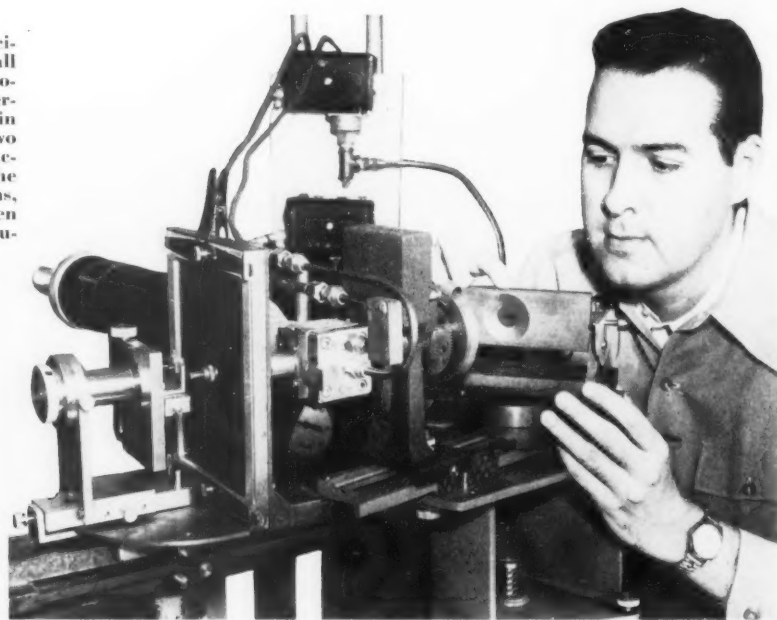
<sup>3</sup> Tensellated stresses, parts I-IV, by F. László, *J. Iron and Steel Inst.*, **147**, 173 (1943); **148**, 137 (1943); **150**, 183 (1944); **152**, 207 (1945).

<sup>4</sup> See Structure of metals, by C. S. Barrett (McGraw-Hill Book Co., Inc., New York, N. Y., 1952).

TABLE 2. Stresses in steel

Specimen			Pearlitic		Spheroidized		Decarburized		Probable error in the stress
Radiation	Bragg angle	Mass absorption coefficient	Strain	Stress	Strain	Stress	Strain	Stress	
Cobalt	81	54	$3.99 \times 10^{-4}$	$\text{lb/in.}^2$ $14.12 \times 10^3$	$1.00 \times 10^{-4}$	$3.56 \times 10^3$	$0.16 \times 10^{-4}$	$0.57 \times 10^3$	$1.92 \times 10^3$
Iron	73	72	1.30	5.57	1.59	6.84	2.45	10.52	5.34
Chromium	78	115	4.20	14.38	3.18	10.89	2.72	9.29	2.02
Weighted average				12.74		6.05		4.58	2.53
Theoretical values				9.2		6.2			

Physicist adjusting angle of incidence of X-ray beam upon small dark rectangular specimen of two-phase brass. The X-ray beam emerges from the circular film holder in front of the specimen. The two phases are "sorted out" by diffraction which results in a pattern on the X-ray film. From such patterns, microscopic stresses that have arisen between the two phases are calculated.



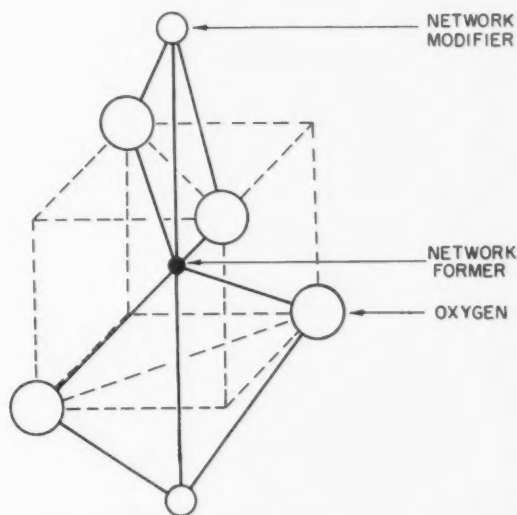
# Structural Interpretation of Immiscibility in Oxide Systems

**P**REVIOUSLY unrelated data on immiscibility in oxide systems have been interpreted structurally under a unified theory.<sup>1</sup> Ernest M. Levin and Stanley Block of the mineral products laboratories have applied crystal chemistry principles to the quantitative interpretation of immiscibility in 19 binary and 24 ternary oxide systems.

Liquid immiscibility is frequently observed in binary and ternary oxide mixtures composed of glass formers, such as silicon dioxide and boric oxide, and glass modifiers, such as barium oxide and magnesium oxide. From a practical standpoint the understanding of the phenomenon of liquid immiscibility in oxide systems is important in the production of industrial products, such as glasses, slags, and cements. From a theoretical standpoint the study of immiscibility offers another approach to the explanation of the structure of oxide melts.

The fundamental equation for immiscibility in a binary system is:  $X = 100M / 0.602ds^3$ , where  $X$  is the weight percent of the modifier;  $M$  its molecular weight;  $d$  the density; and  $s$  the average cation separation. This equation shows that if the density and average cation separation in the modifier-rich liquid are known exactly, its composition can be accurately determined. Alternatively, if the composition and density of the modifier-rich liquid are known, the cation separation may be calculated. The latter procedure was employed to calculate cation separations in known borate and silicate systems. The resulting values were compared with separations calculated from previously suggested coordination configurations.<sup>2</sup> The appropriate coordination could then be determined.

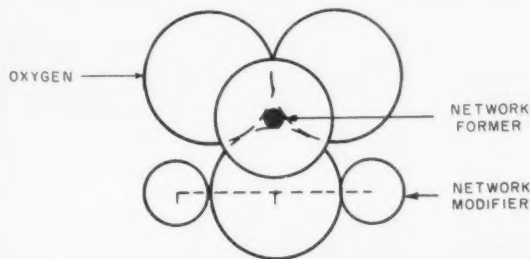
A simple configuration—two cations bonded to the same oxygen atom—was found to occur with divalent cations having ionic radii less than that of  $\text{Ca}^{++}$ , for example  $\text{Cd}^{++}$ ,  $\text{Zn}^{++}$ , and  $\text{Mg}^{++}$ . In this case the ionic separation for a  $180^\circ$  bond angle is twice the sum of the ionic radii of oxygen and the modifier cation. Cations of ionic radii greater than that of  $\text{Ca}^{++}$ —for example,  $\text{Sr}^{++}$ ,  $\text{Pb}^{++}$ , and  $\text{Ba}^{++}$ —are bonded to opposite pairs of oxygen atoms of a tetrahedron. In calculations for this type of ionic separation, the known tetrahedral



Coordination configuration for divalent cations larger than  $\text{Ca}^{++}$ . The Bureau showed that these cations are bonded to opposite pairs of oxygen atoms of a tetrahedron.

distances for  $\text{SiO}_2$  and  $\text{B}_2\text{O}_3$  were used. Calcium was found to occupy a transition position, being mainly in the simpler configuration in the silicate system and in the more intricate configuration in the borate system.

From the cation separation and an approximation for the density, the composition of a modifier-rich liquid can be obtained. To provide another check on the postulated coordination configuration, a second method of calculating immiscibility was developed. The method involves ionic radii, appropriate coordination type, and the volume of space occupied by an oxygen atom. The volume of melt containing one cation is given by the cube of the cation separation. The cation separation is calculated from geometrical considerations of the appropriate coordination type as mentioned above. A correction can be estimated for the volume of space occupied by the modifier cation. The remaining volume is occupied by oxygen atoms, in close packed arrangement, and glass-forming cations, which are located in the interstices and conse-



Simple coordination configuration which was substantiated at the Bureau for modifier divalent cations smaller than  $\text{Ca}^{++}$ . Two cations are bonded to the same oxygen atom at approximately  $180^\circ$  bond angle.

quently do not occupy additional space. From the adjusted volume of oxygen atoms per cation, the number of oxygens per cation can be estimated. From the number of oxygens, the nominal oxide formula for the modifier-rich liquid is computed. Calculations by the two methods give values for composition which agree within the limits of experimental error with most of the recorded data.

Immiscibility in ternary systems can be calculated by application and extension of these same principles. Three types of ternary systems have been considered. The first and simplest type consists of two modifier oxides and a glass former. In these cases the two liquid-one liquid boundary as plotted in a phase diagram is essentially a straight line indicating that immiscibility within the ternary system is an additive function of the two binary immiscibilities.

Coordination configuration postulated at the Bureau for soda acting as a homogenizer. The addition of alkali to an immiscible binary system forms a ternary system which is completely miscible. The alkali or alumina coordinates incompatible structural units of the original melt. The top portion of the figure represents the structure of the magnesium-rich liquid. The bottom portion represents the essential structure of the silica-rich liquid.

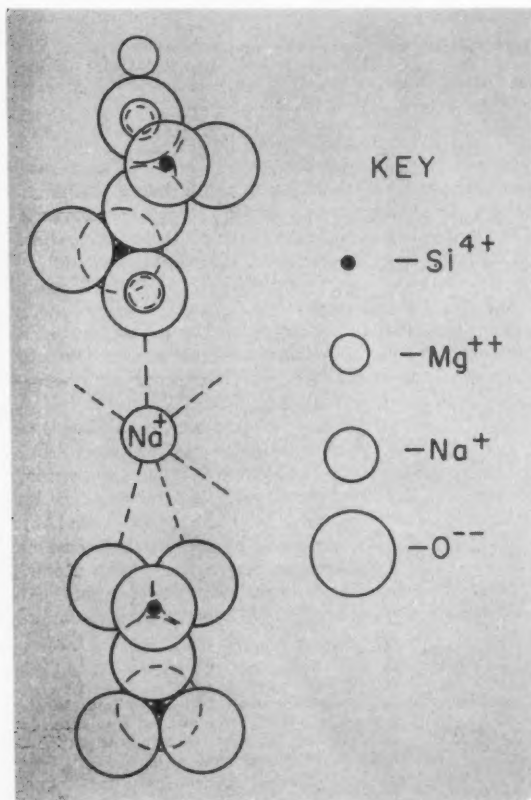


TABLE 1. Comparison of National Bureau of Standards calculated compositions of modifier-rich liquids in borate systems with observed data

Modifier	Experimental	Calculated by—	
		Density	Oxygen volume
BaO	16	18	16
PbO	19	21	18
SrO	21	21	20
CaO *	27	23	22
CdO	39	38	38
ZnO	48	49	46
CoO	42	42	47
MgO	49	52	50

\* Calcium represents the transition cation between the two types of coordination found for cations of radii less than and greater than calcium.

A second type of immiscibility boundary occurs in systems containing two glass formers and one modifier oxide. In this case the maximum amount of modifier in the immiscible liquids occurs within the ternary system. Immiscibility varies inversely as the cube of the cation separation. Therefore a small decrease in cation separation can cause a relatively large increase in immiscibility. A decrease in separation is possible when modifiers in the more involved configuration change to the simpler type or when the usual bond angle found in the simpler type is reduced, as when a cation changes from octahedral to tetrahedral coordination. Calculations based on such premises give good agreement with observed data.

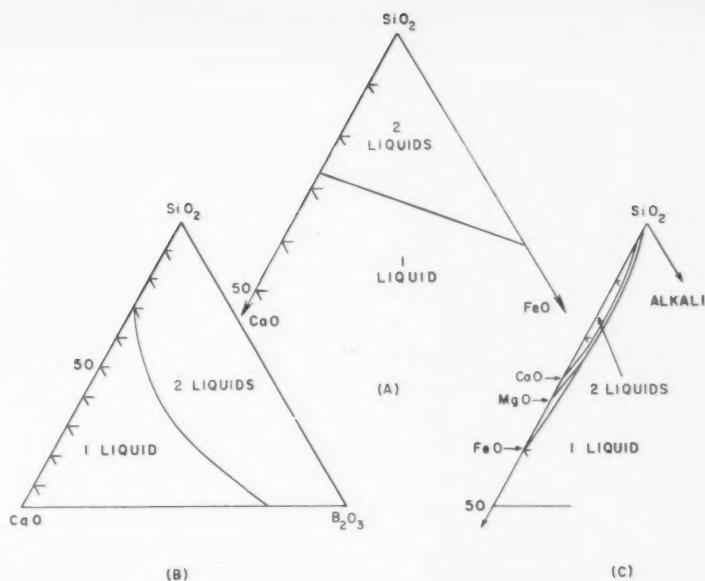
A third type of immiscibility occurs in systems containing an alkali or alumina, a glass former, and a modifier oxide. In such systems immiscibility is confined to a narrow region along the modifier-glass former boundary. Therefore the addition of a small amount of alumina or alkali to a binary system with immiscibility gives complete liquid miscibility. The alumina or alkali acts as a homogenizer to coordinate incompatible structural units of the melt. From postulated configurations consistent with previous deductions two methods are derived which yield a quantitative estimate of the amount of homogenizer required for complete mixing in ternary borate and silicate systems.

Observed phenomena were interpreted on the theory of electrostatic bond strength in conjunction with charge distribution. The analysis of immiscibility has led to numerous implications bearing on the structure of glass. A noteworthy conclusion is that the modifier-rich melt may be considered to be composed of a pseudo-unit cell, the size of which is determined by the cation separation.

<sup>1</sup> Structural interpretation of immiscibility in oxide systems, by Ernest M. Levin and Stanley Block. Part I. Analysis and calculation of immiscibility, *J. Soc. Ceram.* **40**, 95 (March 1957). Part II. Coordination principles applied to immiscibility, *J. Soc. Ceram.* **40**, 113 (April 1957). Part III. Effect of alkalis and alumina in ternary systems, *J. Am. Ceram. Soc.* (in press).

<sup>2</sup> Atomic consideration of immiscibility in glass systems, by B. E. Warren and A. G. Pincus, *J. Am. Ceram. Soc.* **23**, 301 (October 1940).

Three types of immiscibility found in ternary oxide phase diagrams, that were interpreted at the Bureau. (A) Two modifier oxides and a glass former. (B) Two glass formers and one modifier oxide. (C) Alkali or alumina, a glass former, and a modifier oxide.



## Temperature Range of pH Scale Extended

THE BUREAU has recently extended the temperature range in which pH standards are certified. Formerly the pH scale was accurately determined only between 0° and 60° C; now standard pH samples are available from 0° to 95° C.<sup>1</sup> This extension was made possible by the work of V. E. Bower and R. G. Bates of the physical chemistry laboratories.

The standard pH scale was set up to meet the need for accurate measurement of acidity and basicity in aqueous solutions.<sup>2</sup> In the manufacture of many commercial products—for example, paper, textiles, dyes, and ceramics—the rapidity and efficiency of the processes depend upon the accuracy with which pH can be controlled. The NBS standard pH scale is defined in terms of several fixed points in much the same manner as is the International Temperature Scale. The primary standards of the pH scale are solutions whose pH values are only slightly affected by dilution or by accidental contamination with traces of acid or alkali from the walls of the container or from the atmosphere. The substances from which the standard solutions are prepared are, in turn, stable materials which may be obtained as certified standard samples from the Bureau.

In order to assign values to the NBS standards, the electromotive force of cells employing the standards as electrolytes was measured. These cells are specially designed, utilizing the highly reproducible hydrogen and silver-silver-chloride electrodes. Computation of

pH is based upon several reasonable assumed relationships between ionic activities and mean activities. Until recently, data for the standard potential of the silver-silver-chloride electrode above 60° C were not available, so in spite of the demands of industry an extension of the pH scale to temperatures beyond 60° was not possible.

A recent determination of the standard potential of the silver-silver-chloride electrode included measurements from 0° to 95° C.<sup>3</sup> With these new data it became possible to assign pH values over the extended range of temperatures to 5 of the 6 substances used as standards. The sixth substance recently recommended as a highly alkaline standard<sup>4</sup> was not certified for the extended temperature range.

<sup>1</sup> Standards for pH measurement from 60° to 95° C, Vincent E. Bower and Roger G. Bates, *J. Research NBS* **59**, 261 (1957) RP2797.

<sup>2</sup> Standardization of the pH scale, *NBS Tech. News Bul.* **31**, 138 (December 1947).

<sup>3</sup> Standard potential of the silver-silver-chloride electrode from 0° to 95° C and the thermodynamic properties of dilute hydrochloric acid solutions, by Roger G. Bates and Vincent E. Bower, *J. Research NBS* **53**, 283 (1954) RP2546.

<sup>4</sup> Calcium hydroxide as a highly alkaline pH standard, by Roger G. Bates, Vincent E. Bower, and Edgar R. Smith, *J. Research NBS* **56**, 305 (1956) RP2680.



# Calibration of Airplane Cameras

**A** THOROUGHGOING ANALYSIS of random errors that affect the accurate calibration of airplane cameras has just been completed by Francis E. Washer, chief of the optical instruments laboratory.<sup>1</sup> Experiments conducted in the course of the investigation showed that various methods may be employed to eliminate the errors. The work, sponsored in part by the U. S. Air Force, should improve the procedures for testing camera-lens combinations used in aerial photography. One conclusion drawn from the study is that cameras showing an excessive amount of prism effect should not be used for precise photogrammetric mapping.

The purpose of airplane camera calibration is to obtain accurate values of the scale factor used in map interpretation. As airplanes and cameras have improved, requirements placed on lenses have become more stringent. To achieve the required accuracy of camera calibration, testing laboratories have steadily advanced in their techniques. With this advancement, two principal methods of calibration, the visual and the photographic, have evolved; and the latter method is principally employed at the Bureau.

Shortly after World War I, Government agencies started to submit cameras to the Bureau for calibration. At first, visual optical benches were used with good results. Later, a precision lens testing camera<sup>2</sup> was developed and employed. But as exacting requirements and work volume grew, more precise, easier-to-operate equipment was needed, and in 1949 a camera calibrator was designed which met these demands.<sup>3</sup>

The heart of the instrument is a bank of 25 collimators arranged in the form of a cross and suspended from a table with a central circular opening. The

collimators provide distant targets for the camera, which is mounted above the circular opening of the table to undergo test. With the increase in knowledge derived from calibrations made with the new equipment, various factors were recognized that affected the accuracy of the results obtained. The present study was proposed to pinpoint these factors, show their relationship to each other, and develop methods, where possible, to overcome them.

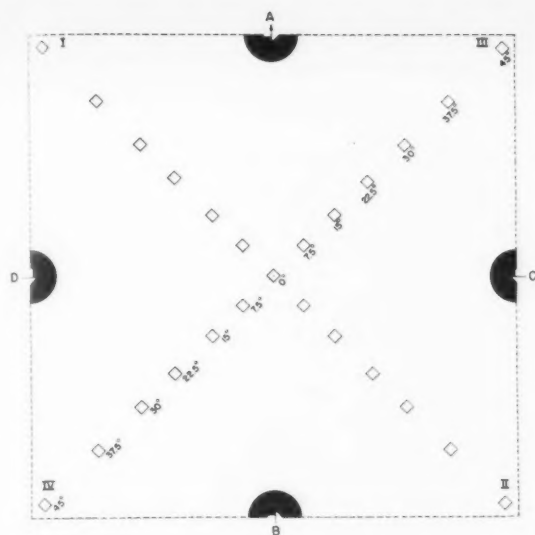
Investigations disclosed that among the principal sources of error are those inherent in measuring techniques. These include errors in angle measurement and errors in linear scale on the test negative. In addition, errors were found to result from curvature of the plates used in making the test negative.

Asymmetric distortion is introduced into a lens-camera combination when the camera is incorrectly aligned for calibration—in other words, when the camera is “tipped.” Experiments were conducted to determine the effect of camera tipping on the displacement of the central image of a distant object from the original position of the principal point of autocollimation (also known as the “center cross”). Methods were found for accurately determining the magnitude of the angle of camera tipping for both equal and unequal opposite angles. Thus, the principal point of autocollimation can be computed from the measured values of distortion. It was shown that in the absence of prism effect, the “point of symmetry” is identical with the principal point of autocollimation.

A detailed study was made of prism effect. In the cameras calibrated at the Bureau during the past 20 years, no instance occurred in which the asymmetric part of the observed distortion pattern could not in

The camera calibrator developed by the Bureau is tested for accuracy in the optical instrument laboratory. The test involves determination of the angular deviation between collimators in the collimator bank beneath the table. Light from any two adjacent collimators is reflected by a biprism mounted above the hole in the circular plate in such a way as to produce an image in the eyepiece of the telescope when the proper angular difference exists between the two collimators. The adjustment necessary to bring the image into the field of view in the telescope, as read on the micrometer below the eyepiece, indicates the amount by which the angular position of the collimators must be corrected.





Schematic drawing of test negative made with NBS camera calibrator showing the relative location of the images of the collimator targets and the collimation index markers (A, B, C, D) on a finished test negative.

large measure be attributed to a simple thin prism. Usually a small residual distortion remained which was not fully accounted for; such distortion, though, is negligibly small when compared to the initial values of the asymmetric distortion. The effect of a thin prism in the optical path can be produced by placing a filter with nonparallel surfaces in front of the lens. This effect can also be produced by small lens decentrations. The results are similar to those produced by camera tipping.

Prism effect as related to the principal point was investigated. The term "principal point" in photogrammetry refers to the point of intersection of a perpendicular dropped from the interior perspective center of the camera to the plane of the photograph. When a camera under calibration is so aligned that the focal plane of the camera is normal to the line which joins the front nodal point of the lens to a distant object, the central image of the distant object is located at the principal point of autocollimation. If asymmetric values of distortion are then found, the principal

Double exposure photograph demonstrating the existence of radial asymmetric and tangential distortion produced by a prism. The bases of the arrows show the initial undeviated image points; the tips of the arrows show the location of the same points after a 5.00 diopter prism was placed in front of the lens. Radial asymmetric distortion is present along the III-IV diagonal. The pronounced bowing resulting from tangential distortion may be seen along the I-II diagonal.

point does not coincide with the principal point of autocollimation and, in addition, prism effect is present.

It is generally accepted that both radial asymmetric distortion and tangential distortion may be caused by prism effect although some questions persist regarding the relative magnitudes. In an experiment with a 5.00 diopter prism placed in front of the lens, it was found that radial asymmetric distortion is the larger of the two.

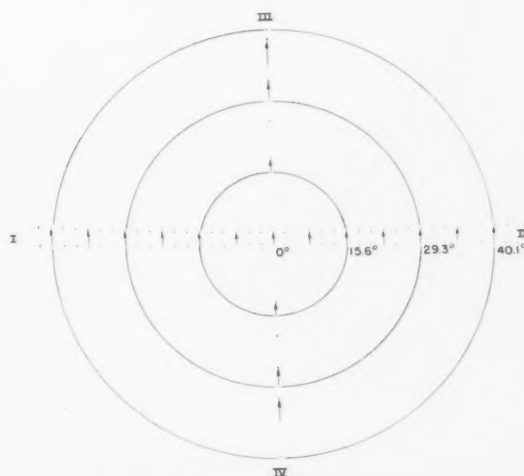
An analysis was made of the errors resulting from curvature of the plates used in making the test negative. A striking reduction in the errors was noted with increasing thickness of the photographic plates. It was shown that the thicker plates are less likely to warp or depart from their initial state of planeness.

Recognition of the factors outlined above is the first step in eliminating sources of error inherent in airplane camera calibration. The methods developed by the Bureau for overcoming these factors should prove of considerable benefit to testing laboratories charged with certifying the accuracy of camera-lens combinations.

<sup>1</sup>For further technical information, see the following papers by Francis E. Washer: Effect of camera tipping on the location of the principal point, *J. Research NBS* **57**, 31 (1956) RP2691; Sources of error in various methods of airplane camera calibration, *Photogrammetric Engineering* **22**, 727 (1956); A simplified method of locating the point of symmetry, *ibid.* **23**, 75 (1957); The effect of prism on the location of the principal point, *ibid.* **23**, 520 (1957); Prism effect, camera tipping, and tangential distortion, *ibid.* (in press).

<sup>2</sup>Specifications for a precision-mapping camera, *NBS Tech. News Bul. No. 256*, 71 (1938); Precision camera for testing lenses, by Irvine C. Gardner and Frank A. Case, *J. Research NBS* **13**, 449 (1937) RP984.

<sup>3</sup>New precision camera calibrator, *NBS Tech. News Bul.* **33**, 8 (January 1949); Calibration of precision airplane mapping cameras, by Francis E. Washer and Frank A. Case, *J. Research NBS* **45**, 1 (1950) RP2108; and *Photogrammetric Engineering* **16**, 502 (1950).



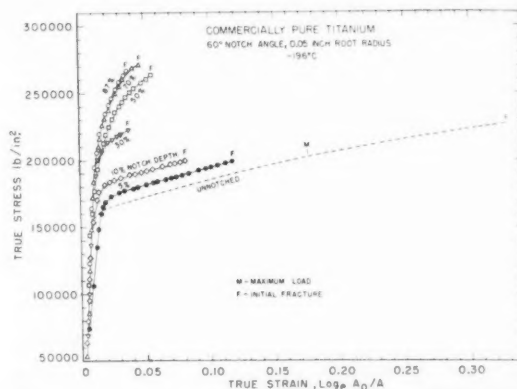
# Effects of Notch Depth and Low Temperature on the Tensile Properties of Titanium

AS PART of a general program to evaluate the deformation of metals, the Bureau has recently studied the effects of notch geometry and low temperature on the mechanical properties of titanium. Measuring the strength and ductility characteristics of an annealed, commercially pure titanium, G. W. Geil and N. L. Carwile of the thermal metallurgy laboratory have found that strength indices—i. e., resistance to flow, notch strength, true stress at maximum load, and fracture stress—are increased and tensile ductility decreased by increasing the notch depth or by lowering the test temperatures.<sup>1</sup>

A high strength-to-weight ratio combined with good corrosion resistance makes titanium a promising structural material for use in aircraft, guided missiles, airborne equipment, and in applications involving severe corrosive conditions. To realize fully such applications, however, further knowledge of the mechanical properties of titanium over a wide range of conditions is urgently needed.

Failure of metals in service, especially at subzero temperatures, often results from a local condition of multiaxial tension due to the presence of notches either as design features or as defects. Some metals become noticeably embrittled at low temperature, and notches with multiaxial stresses often accentuate this embrittlement. Thus, the combined effect of notching and low temperatures should be of considerable interest to designers employing titanium, especially in low-temperature applications.

In the present investigation, which was partially sponsored by the Wright Air Development Center, notched and unnotched specimens were slowly strained to fracture in tension at temperatures ranging from  $+150^{\circ}$  or  $+100^{\circ}$  to  $-196^{\circ}$  C. The interstitial content of the titanium used was as follows (percent by weight): Oxygen, 0.21; nitrogen, 0.04; hydrogen, 0.012; carbon, 0.04. The notched tensile specimens were of circular cross section with a circumferential  $60^{\circ}$  angle V-notch, 0.05 inch root radius and different depths. Simultaneous load and diameter measurements were made throughout each tension test. Results indicate that the resistance of the metal to deformation,



True stress-true strain relations obtained in tension tests at  $-196^{\circ}$  C on notched specimens of commercially pure titanium. Strength was increased and tensile ductility decreased with an increase in the notch depth.

as measured by the tensile true stress (ratio of current load to current minimum cross-sectional area), increased with increased true strain, notch depth, or lowering of temperature. The relatively large rise in resistance with the deep notches can be attributed directly to the increase in triaxiality, i. e., ratio of the radial stress to the axial stress. Even for a very shallow notch, the induced multiaxial stress system is significant. The resistance also increased greatly with a lowering of temperature within the range of  $+150^{\circ}$  to  $-196^{\circ}$  C; at  $-196^{\circ}$  C it was more than twice that at  $+150^{\circ}$  C.

Variations in the notch strength (ratio of highest load on the specimen to the initial minimum cross-sectional area) were noted with different notch depths and temperatures. The strength increased linearly with increase in notch depth to about 50 percent and thereafter increased at a declining rate with further depth. At  $-196^{\circ}$  C, the notch strength of the deep-notched specimens was nearly three times the tensile strength of the titanium at  $+25^{\circ}$  C.



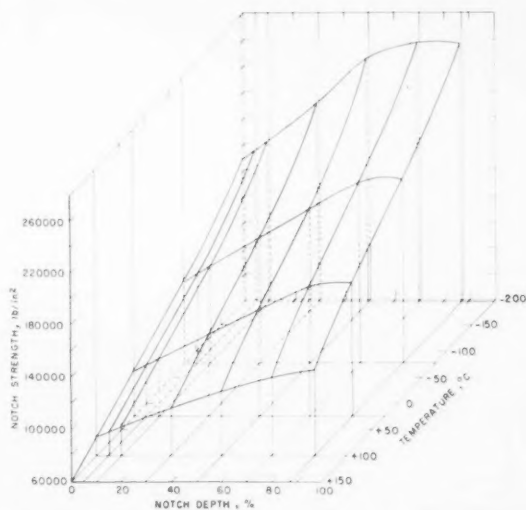
Fracture surfaces (magnified 2.5 times) of notched titanium specimens,  $60^{\circ}$  angle and 0.05-in. root radius, that were extended in tension to fracture at  $-78^{\circ}$  C. The arrows point to the position of the fracture initiation. With a notch depth of 50 percent or less, the fracture was initiated at a point at or near the base of the notch and then propagated diametrically across the specimen. However, with a notch depth over 50 percent, the fracture started at a point near the axis and then propagated to the periphery.



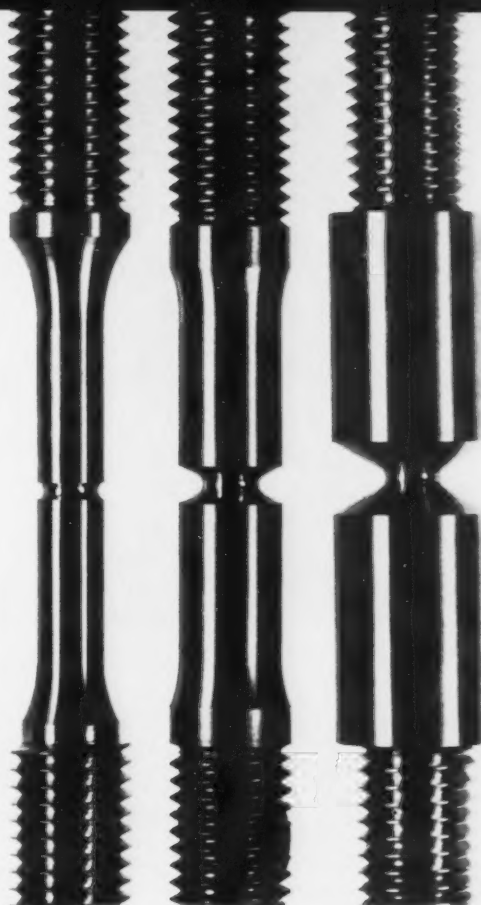
The ductility of the titanium in tension, as measured by the amount of true strain at fracture, was greatly reduced by the presence of notches and low temperatures. The ductility decreased very rapidly with increase in notch depth to about 30 percent and from then on changed only slightly. The ductility of all of the notched tensile specimens at  $-196^{\circ}$  and of the deep-notched specimens at  $-78^{\circ}$  C was so limited that a normal maximum load condition was not attained.

In general, the fracture stress of the titanium specimens was increased either by a lowering of temperature or by an increase in triaxiality that accompanied notches with depth in excess of 10 percent. However, for depths of 10 percent or less, a decrease in the fracture stress was observed at room and subzero temperatures, even though the effect of the triaxiality was to increase the stress. The loss in the fracture stress resulting from the reduced ductility of these specimens was apparently greater than the rise in the stress level that accompanied the relatively small triaxiality.

The position of fracture initiation of the notched tensile specimens was dependent upon the geometry of the notch, the accompanying stress concentration, and the multiaxial stresses. With notch depths up to 50 percent, the effect of the stress concentration and resulting strain- and work-hardening gradients near the root of the notch was the dominant factor; fracture was initiated in these specimens near the base of the notch. However, with notch depths greater than 50 percent, the fracture was initiated near the axis by the high triaxiality. The relative effect of these two factors depended only slightly on the test temperature for all except the deep-notched specimens, which retained very little ductility at  $-196^{\circ}$  C.



Variation of the notch strength of annealed commercially-pure titanium with notch depth and temperature. The notch strength is expressed as the ratio of the highest load attained on the tensile specimen to the initial minimum cross-sectional area at the base of the 0.05-in. root radius,  $60^{\circ}$  V-notch.

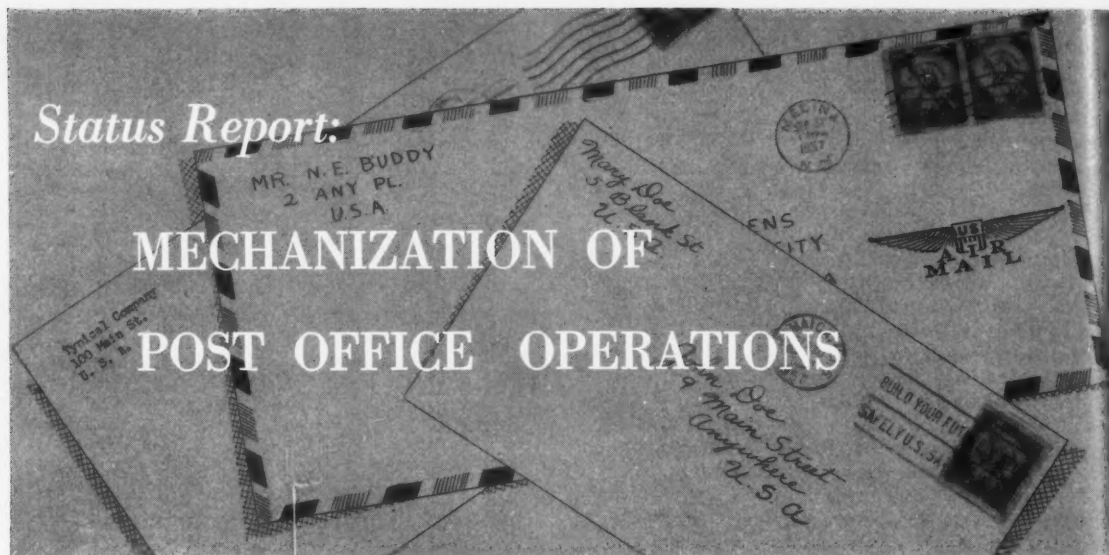


Typical notched specimens used to investigate the effects of notch geometry and temperature on the tensile properties of titanium. The annealed specimens were machined to a constant diameter of 0.350 in. at the base of a 0.05-in. root radius,  $60^{\circ}$  V-notch. Notch depth was varied by changing the diameter of the cylindrical portion of the specimen adjacent to the notch. The depth is expressed as the percentage of the cross-sectional area removed in machining the notch in the specimen.

Impact tests were also made on Charpy V-notch specimens at temperatures ranging from  $+300^{\circ}$  to  $-196^{\circ}$  C to determine the impact notch toughness of the annealed titanium. The transition from ductile to brittle behavior in these tests occurred within the range of  $+125^{\circ}$  to  $+80^{\circ}$  C; only a small amount of the notch toughness was retained by the metal at  $-196^{\circ}$  C.

Investigations are now in progress at the Bureau to determine the effect of other features of notch geometry, such as notch angle and root radius, on the deformation and fracture characteristics of the titanium in tension.

<sup>1</sup> For further technical details, see Some effects of low temperature and notch depth on the mechanical behavior of an annealed commercially pure titanium, G. W. Geil and N. L. Carwile, *J. Research NBS* 59, 215 (1957) RP2790.



**M**ETHODS and machines to speed the handling of mail are the objectives of a current research program at the National Bureau of Standards. Under the sponsorship of the Post Office Department, the Bureau has established the basic principles of a system for automatically sorting letter mail and is presently supervising development of both large- and small-capacity prototype machines that embody the concepts of this system. The task is being conducted by a group of scientists and engineers from diverse areas throughout the Bureau whose efforts are coordinated by I. Rotkin (on loan from the Diamond Ordnance Fuze Laboratories). The Bureau is assisting the Post Office Department as part of its advisory service and because of its specialized experience in the field of data processing machines and electronic equipment. Most of the actual equipment construction is being placed in the hands of private industry.

The handling of mail is now a major economic problem within the Government. The Post Office Department estimates that in 1956 it handled over 43 billion pieces of letter mail alone. The amount of mail has been increasing exponentially almost since the inception of the postal service, and indications are that this rate of expansion will continue for years to come. To keep up with this tremendous growth, the Post Office Department has been seeking mechanized methods to assist its personnel. In recent years, certain engineering techniques have been perfected that could well be applied to the mechanical sorting of mail. The potentialities of some of these techniques—such as punched card sorting and coded character reading—have been investigated by the Bureau to see how they could be applied to alleviate the large-volume high-speed letter sorting problem.

The Bureau's first task was to become familiar with the organization and operations of the Post Office Department, particularly present methods of letter mail sorting. Through the cooperation of the Department, study tours were arranged at a number of post offices. Glossaries of postal terms, sample mail distribution schemes, statistical data relevant to mail distribution, and similar publications supplied further information. From direct observation during the tours and from a study of the publications, a broad over-all picture was formed of the nature and magnitude of the letter mail sorting problem.

Detailed analyses of sorting operations were then begun and the development of specifications for sorting equipment undertaken. First, the statistical distribution of the physical characteristics of letters including size, shape, color, and location of address was studied. Then statistical patterns of sorting systems were analyzed for outgoing and incoming mail in post offices. Finally, coding systems were developed for abbreviating addresses in a standardized yet unique manner for efficient use with mechanical sorting equipment. It was decided that, if envelopes were imprinted with such abbreviated addresses in a dot code similar to teletype code, all sorting could be done by machinery. Electronic readers for dot codes are already well developed, whereas readers for printed addresses are in the early stages of development and no satisfactory readers have been proposed for handwritten addresses.

Once basic principles of handling letter mail were established, the next step was to design and to build the equipment. The Bureau undertook the development of one type of sorting system and invited industry to submit proposals for similar systems based on a general presentation of the problem. As a part of this develop-

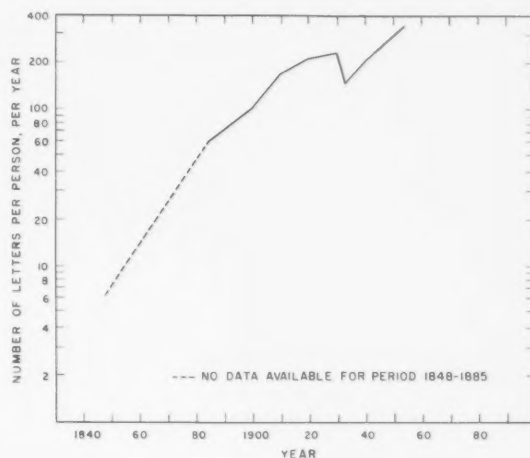
ment program, a contract was awarded to the Rabinow Engineering Co. to develop the elements of its proposed sorting machine which appeared to be suitable for use in large post offices. In addition to designing the mechanical elements of the machine, this firm also developed (1) an electro-mechanical-optical translator and an alternative magnetic core-translator for converting address codes into machine instructions for distribution of letters by means of a conveyor to proper output bins; (2) a code printer with equipment for presenting envelopes to a human operator and for imprinting dot codes on the envelopes according to instructions by the operator via a keyboard; and (3) a code reader with a rapid letter feed system for converting dot-coded addresses into electrical signals for input to the translator.

Before mail is presented to any machine, it goes through several auxiliary operations. It is first culled to remove the too large, too small, or too thick pieces. The letters are faced to orient the stamps properly and to present all the addresses same side up. The mail is then fed into the stamp cancelling machine. At this point it is ready to be presented to the coding operators.

The operator reads the address on the envelope and operates a keyboard similar to a typewriter keyboard. By following certain fixed and simple rules of abbreviation, the operator imprints on the back of the envelope, in dot code form, a standardized abbreviated version of the address on the envelope. The degree of abbreviation depends on the volume of mail that is normally sent to the address in question. Post offices, streets, and individual addresses which receive very large vol-

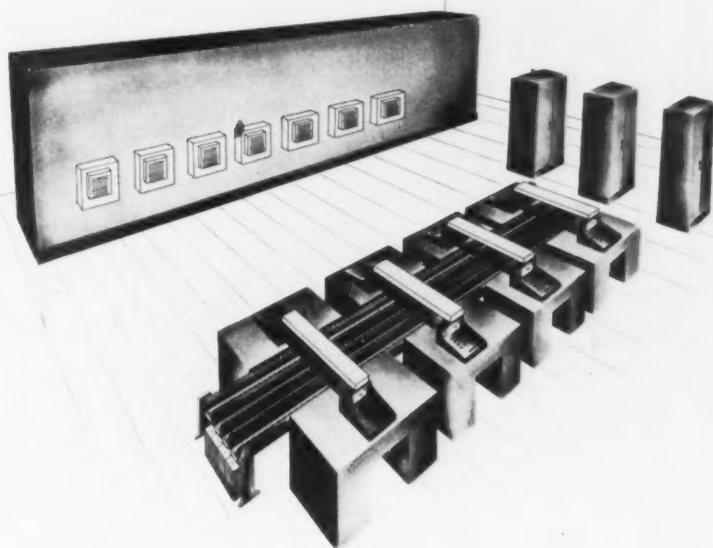
umes of mail may be given unique single-character codes to save the coding operator's time.

The letter is then mechanically transported to a code reader. Here electronic devices produce electrical signals from the dot code, which in turn are passed on to a translator. The translator is an electronic or electro-

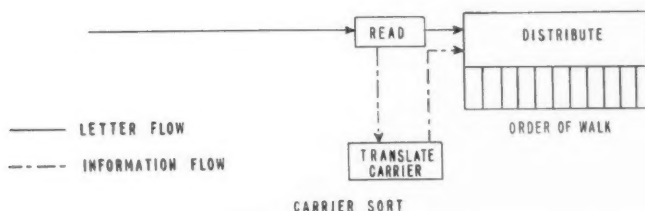
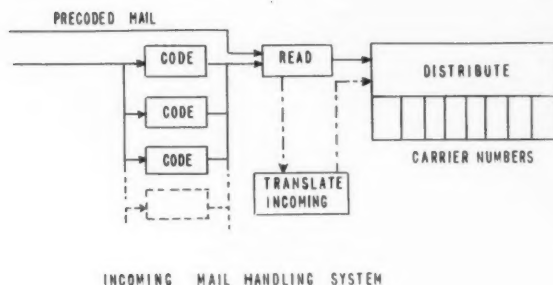
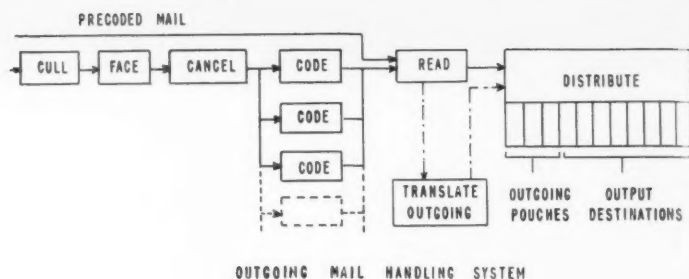


**Graph of mail growth.** This growth has been increasing exponentially almost since the inception of the postal service, and indications are that this expansion will continue for years to come. For this reason, the Post Office Department has been seeking mechanized methods of mail handling to assist its personnel.

Artist's conception of one section of a mechanized post office. In the foreground are the code printing stations. Mail that has been culled, faced, and cancelled is brought to these stations. Human operators read the addresses and operate the keyboards to rewrite the addresses in a dot code form that can be read by machine. The mail is then transported to the boxes mounted on the large machine in the rear. Here the coded addresses are read, and the resulting electrical signals are sent to the translators at the right. There are three translators: For incoming mail, for outgoing mail, and for carrier mail. The translators decide where each letter is to go, and send information back to the distributor representing the output bin into which the letter is to be sorted.



Block diagrams of the mail sorting system under development. Schemes show handling systems for outgoing and incoming mail, and for sorting mail in the order of the carrier's route.



mechanical device which converts the abbreviated address information from the dot code into another set of electrical signals, identifying a proper destination bin in the distributor. The translator incorporates a memory which contains all of the necessary destination information. This destination information from the translator is fed to the distributor. The distributor accepts the envelopes from the reader and the destination information from the translator, and delivers the letter to the proper output destination bin. From these output bins, letters are removed, tied in bundles, and put into outgoing pouches, or in the case of incoming mail sent to the carrier stations.

Mail which has already been coded at some other location bypasses the culling, facing, cancelling, and coding operations and enters directly into the reader. Incoming mail is sorted in a similar manner except that culling, facing, and cancelling may be omitted because these operations will have been performed elsewhere. The translator for incoming mail would have impressed into its memory the incoming mail scheme, and the letters would be delivered to output bins according to carrier numbers. The same machine can sort either incoming or outgoing mail simply by changing the in-

formation stored in its memory. Changes in the distribution system do not require altering the dot code. Only the information in the memory—which can be easily modified—need be changed to keep abreast of a growing postal delivery system.

At the Bureau a different sorting device is being developed which promises to be more compact than other proposed equipment and may save space in post offices. This device is not expected to be suitable for use in large sorting offices because its use requires sorting the same batch of mail several times. It is, however, well adapted to the scale of operations in smaller offices.

A parallel problem associated with facing and cancelling letter mail is under consideration. A method is being sought to make a postage stamp more easily recognized by electro-optical devices as a unique element on an envelope. Fluorescent and phosphorescent dyes, magnetic and conducting inks, and metallic laminates are some of the possibilities that have been investigated. The most promising results seem to be with a phosphorescent ink now being perfected at the Bureau. This ink will also be used in imprinting the code on the envelope.



WITH more than 500 engineers and scientists in attendance, the 1957 Cryogenic Engineering Conference met at the Boulder Laboratories of the National Bureau of Standards, August 19 to 21. The large attendance and the broad variety of researches discussed in the 44 delivered papers gave evidence that the low-temperature field continues to attract increasing attention from industry and defense. The papers dealt not only with recent low-temperature engineering techniques and experimental discoveries, but also with the theoretical problems of low-temperature research.

The meeting was called to order by R. B. Scott, Chief of the NBS Cryogenic Engineering Laboratory; and Dr. F. W. Brown, Director of the Boulder Laboratories, greeted the participants in a brief introductory talk. The researches reported to the Conference fell into four major categories that dealt with cryogenic processes, applications, equipment, and properties.

### Processes

Although the process of low temperature refrigeration and gas separation was worked out nearly a half century ago, important improvements are still being developed, conference papers brought out, with the result that liquefaction processes are becoming more efficient and less expensive. The most striking, recent illustration of this fact was described in a series of papers on the use of the catalyst, hydrous-ferric oxide, to convert liquid hydrogen from the ortho to para state during liquefaction. As a result, the liquid is not evaporated by conversion which would otherwise take place in the storage vessel.<sup>1</sup>

C. R. Class, R. P. Spero, and G. E. McIntosh (Beech Aircraft Corp.) told of a theoretical study that showed how catalysts, when properly located to convert ortho to parahydrogen in the gas phase of a parahydrogen liquefaction cycle, are more effective in increasing yield

than either minor-cycle modification or major-expansion engine improvement.

Design data for ortho-parahydrogen converters were presented by D. H. Weitzel, C. C. VanValin, and J. W. Draper of the NBS Cryogenic Engineering Laboratory. They pointed out that the most important variables in such designs are the conditions of temperature, pressure, feed composition, and space velocity (or contact time) under which the conversion proceeds.

W. A. Wilson, of NBS, in cooperation with D. H. Weitzel, then showed the favorable comparison between the laboratory-scale studies and results obtained in the large Bureau liquefier when a vapor-phase converter was used operating in a 71°K bath. It was pointed out that conversion at higher temperature provides increased liquefaction-cycle efficiency.

T. W. Schaffers (North American Philips Co.) described a gas liquefier of nonconventional design and modest cost which can produce five quarts of liquid air an hour.

### Applications

In the discussions devoted to cryogenic applications, R. E. Brown (Navy Bureau of Aeronautics), expressed the opinion that helium could be conveniently liquefied at production plants so it could be shipped by air or tank cars to points of use. The cost of transporting helium as a liquid, he pointed out, is about one-fifth the cost of transporting the same amount of it as a high pressure gas. The Navy Department is critically concerned with achieving the most economical production and transportation of helium since it requires large quantities for a wide variety of uses including welding and airship inflation, and for its role in the nation's missile program.

For some time the Bureau has been investigating the technical feasibility of such a plan as that proposed by



Mr. Brown. The Boulder Laboratories have worked out designs for a railroad tank car capable of transporting 60,000 liters (15,000 gallons) of helium as a liquid.

At Air Products, Inc., a large-scale liquid oxygen and liquid nitrogen unit has been developed to satisfy requirements of the Air Force Missile program, according to a paper delivered by W. J. Scharle. The unit has a high efficiency with consequent low operating cost, minimum utility requirements (including no water consumption) and maximum mobility compatible with large-scale liquid production. The production rate of the unit is 56,000 liters per day of liquid oxygen plus 8,000 liters per day of liquid nitrogen, each at 99.5 percent purity.

W. W. Aton (Linde Co.), told of unattended oxygen plants that range in capacity from less than 10 million ft<sup>3</sup> to more than 100 million ft<sup>3</sup> per month. These plants function in conjunction with liquid oxygen storage supply facilities that consist of a storage tank and the required auxiliaries for pressurizing, vaporizing, and delivering gaseous oxygen into the customer's pipeline.

A breakthrough on a problem that has challenged cryogenic scientists for some time was announced by S. Greenfield of Rocketdyne. Rocket engineers there have found a solution to the problem of keeping the pressurizing gas, nitrogen, from mixing with the liquid oxygen used as a propellant.

Working under an Air Force contract, Rocketdyne has designed a perforated inlet tube that slows down the nitrogen as it is diffused into the liquid oxygen chamber. Instead of mixing with the liquid oxygen, the nitrogen bounces against the top of the tank and then gently blankets the liquid.

It was stated that 10 to 20 times less dilution takes place with the new inlet tube. This may increase the range of long-range rocket-powered missiles by as much as 30 percent. It is also planned to try replacing the perforated tube with a tube made of metal mesh; the indications are that this tube will be even more effective.

## Equipment

The 14 papers delivered on cryogenic equipment included discussions of the use of liquid helium in an atomic reactor in order to study radiation effects at extremely low temperatures; piston-type high pressure aircraft cryogenic pumps; and a cryostat for liquid nitrogen cooling of rocket-borne photomultiplier tubes.

V. E. Isakson, C. D. Holben, and C. V. Fogelberg (Beech Aircraft Corp.) reported on a large-size, non-refrigerated vessel that stores and transports liquid hydrogen. This vessel is insulated with evacuated powders and does not use a radiation shield. Heat leak calculations predict loss rates of about 2 percent per day; measured values are somewhat less. The Dewar is mounted on a semitrailer chassis, but it can be removed where a skid-mounted Dewar is required.

The fact that no one thermometer is suitable from the entire temperature range of 1° to 300° K. led to a study reported by R. D. Goodwin of the Boulder Laboratories. His experiments show that thermometer

power may be reduced by using unsymmetrical resistance bridges, by using specific bridge circuits in conjunction with various types of thermometers, and by matching the bridge source and detector input impedances.

## Properties

Among the more than a dozen papers on the topic of cryogenic properties, the one by R. M. McClintock and M. J. Hiza (NBS) described the properties of a filled-epoxy resin adhesive which has been found capable of holding light metals together with a strength of 800 psi at a temperature of 20° K. The research was necessitated when design of a liquid-hydrogen cooled electromagnet being developed at Los Alamos Scientific Laboratory required that copper coils be joined with a resin. These coils are subjected to sudden and extreme decreases in temperature, so that resin was needed that would contract in the same ratio as the copper parts that bonded together.

S. C. Huntley (NACA) discussed the problem of heat leak associated with increase in pressure when cryogenic liquids are enclosed in a container. He reported on an experimental study that determined the factors controlling pressure rise in a closed liquid-nitrogen container. Liquid and vapor temperatures were measured in a 30 by 93 inch Dewar as the container was allowed to pressurize with time. Heat leak rate was controlled by varying vacuum pressure in the jacket of the Dewar. Liquid level was varied from one-third to two-thirds of container capacity.

It was shown that because of free convection a liquid-temperature gradient exists which becomes more severe with time; the free surface temperature controls the pressure; and mixing the liquid extends the time required to reach limiting pressure. It was also shown that the temperature gradient exists in the vapor and that mixing the vapor may result in a substantial increase in pressure.

Other papers on cryogenic properties dealt with such topics as "Calculation of Gaseous Heat Conduction in Dewars", "Measurements of Thermal Stresses at -320° F by Strain Gages", and "Friction Studies of Various Materials in Liquid Nitrogen".

A highlight of the conference was the banquet address delivered by C. J. Gorter, Director of the Kamerlingh Onnes Laboratory in Leiden, The Netherlands. He invited all participants to attend the low-temperature conferences to be held next year in The Netherlands at the University of Delft (June 18-20) and at the University of Leiden (June 23-25). The conferences will commemorate the 50th anniversary of the first liquefaction of helium, accomplished by the Dutch scientist, Prof. Kamerlingh Onnes.

It was announced at the close of the sessions that the 1958 Cryogenic Engineering Conference will be held September 3 to 5 at the Massachusetts Institute of Technology. The invitation for the meeting was extended by Professor S. C. Collins, head of the M. I. T. cryogenic engineering laboratory.

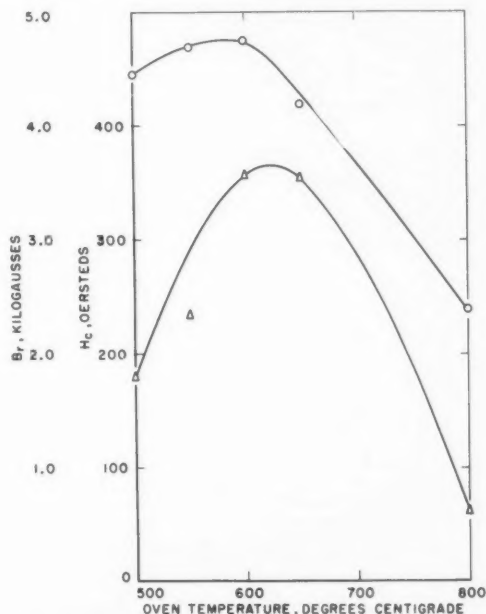
<sup>1</sup> Catalyst for parahydrogen production, *NBS Tech. News Bul.* 41, 154 (Oct. 1957).

# Extremely Small Permanent Magnets



The Cunife magnet, as small in diameter as a human hair, is dwarfed by an ordinary paperclip.

**PERMANENT MAGNETS** as small in diameter as a human hair have been made from Cunife at the Bureau. Cunife is an alloy of approximately 60 percent copper, 20 percent nickel, and 20 percent iron with an unusual combination of magnetic and mechanical properties. For example, Cunife—instead of requiring casting or sintering into a desired shape like most highly coercive magnet materials—can be cold drawn. This ductility suggested its use for very small magnets, which have important instrumentation applications. In an effort to determine its suitability for such applications, I. L. Cooter and R. E. Mundy of the magnetic measurement laboratory carried out an investigation

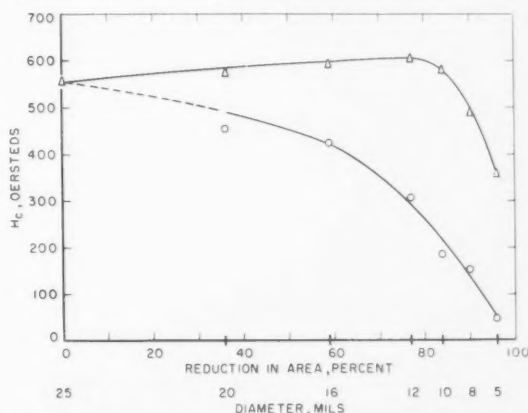


Graph showing the value of the coercive force  $H_c$  (lower curve) and residual induction  $B_r$  (upper curve) of Cunife wire, 0.005 in. in diameter when heat treated at various temperatures. Experiments show that heating restores the magnetic properties of cold-drawn Cunife wire a few thousandths of an inch in diameter.

of Cunife's magnetic properties when cold drawn into fine wires.

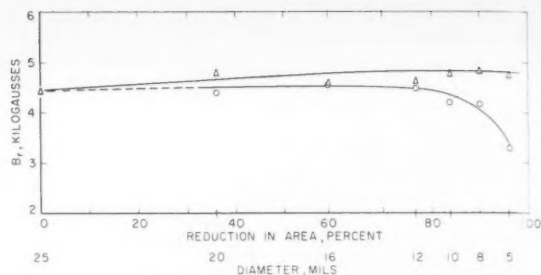
Several investigators have reported on the magnetic properties of Cunife wire and on the effects of cold working and subsequent heat treatment. Their results have shown that even if the material is cold worked to the point at which the magnetic properties are adversely affected, the initial magnetic properties may be recovered or improved by a simple heat treatment or baking. These reports, however, pertained only to the larger wire sizes. No data were available on the magnetic properties of Cunife drawn to wire a few thousandths of an inch in diameter.

The Bureau's evaluation entailed cold drawing Cunife to a diameter at which its magnetic properties change and then observing the effect of various heating procedures on the restoration of magnetic properties. Cunife is available commercially in the form of wire



Graph showing the dependency of coercive force on the area of Cunife wire. The upper curve was obtained with heat-treated wire and the lower with wire that had been cold drawn only. The Bureau found that heat treatment restores the magnetic properties of the material only when the reduction in area of the 0.025-in. diameter wire tested does not exceed 85 percent.

Graph showing that the residual induction of Cunife remains approximately constant during cold drawing until the reduction in area of 0.025-in. diameter wire exceeds 80 percent (lower curve). Residual induction then decreases sharply for further decrease in area. Heat treatment restores the residual induction to its value before drawing (upper curve).



with a diameter of 0.025 in. This wire was first cold drawn to 0.020 in. through carbonyl dies and further reduced to 0.005 in. through diamond dies. At various stages of reduction samples were cut from the coil of wire for later measurements.

Since the maximum heat-treating temperature affects the final magnetic properties, several heat-treating temperatures were tried. It was found that a heat-treating temperature between 610° and 620° C gives a maximum value for the coercive force for all wire diameters. The final procedure adopted was to heat the wires embedded in iron filings to 610° C, to hold them at this temperature for 1 hour, and then to allow them to cool slowly to room temperature. This produced wire that was bright and showed no noticeable signs of surface oxidation.

The normal induction and demagnetization curves of the Cunife wires were obtained using a High-H permeameter and a calibrated ballistic galvanometer. The demagnetization curves were obtained from a maximum magnetizing force of 300 oersteds.

The decrease in coercive force is dependent upon the reduction in area of the wire. For an 0.025-in. wire initially in the annealed condition, the percentage of reduction in area was also the percentage of cold work-

ing. As a result of the cold reduction of this wire from 0.025 to 0.005 in., the coercive force decreased from 550 to 50 oersteds. Subsequent heat treatment restored the initial coercive force until the reduction in area exceeded 85 percent—that is, the diameter was reduced to approximately 10 mils. Further reduction in area caused a sharp decrease in the value of the coercive force after heat treatment.

The value of the residual induction was found to remain approximately constant until the reduction in area exceeded 80 percent. It then decreased sharply for further increases in cold reduction. After the successive samples of wire were heat treated, the residual induction for each wire size increased to or exceeded the initial value for the 0.025-in. diameter wire.

It is therefore possible to produce permanent magnets of Cunife as small as 0.005 in. in diameter by cold drawing larger sizes of the material through dies. If the cold-drawn wire is subjected to a simple heat treatment, the permanent magnet properties of the material are substantially improved and are satisfactory for many magnetometer and galvanometer uses.

## Rapid Determination of Unhydrated Magnesia in Lime Hydrates

A RAPID METHOD for determining unhydrated magnesia,  $MgO$ , in dolomitic lime hydrate has been developed by E. Trattner of the concreting materials laboratory.<sup>1</sup> The lime is treated with high-pressure steam, which results in complete hydration of the residual free  $MgO$ . The weight gain resulting from the forced hydration is taken as a measure of the unhydrated  $MgO$  in the sample. This method gives results which are reproducible and which agree well with those obtained by the costly and time-consuming chemical-analysis method previously required.

Hydrated lime produced in this country is either a high-calcium type which consists almost entirely of calcium hydroxide, or a dolomitic type which contains varying large proportions of magnesium hydroxide and magnesia. Since 1937, a series of investigations by the Bureau have indicated that certain types of white-coat and plaster failures were caused by the presence of large amounts of unhydrated  $MgO$  in the dolomitic lime hydrate.<sup>2</sup> A limit on the unhydrated

oxide content of hydrated limes was therefore suggested by the Bureau and subsequently incorporated into a specification by the American Society for Testing Materials.

A method for the determination of free  $MgO$  which does not involve detailed chemical analysis has been needed. Prospective purchasers of structural lime with no interest in its chemical composition aside from its unhydrated oxide content need a rapid and inexpensive test. Such a test should also be of great help in day-to-day plant control.

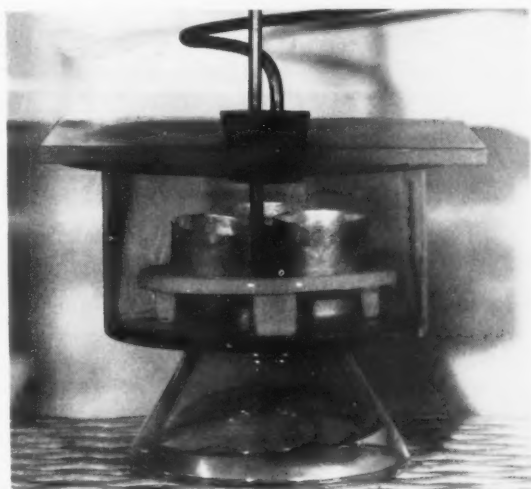
The standard chemical method for determining the unhydrated oxide content of hydrated lime depends on the assumption that the  $CaO$  is completely hydrated and the  $MgO$  only partially hydrated. The total amount of water determined in the analysis is sufficient to hydrate all the  $CaO$  and part of the  $MgO$ . The remaining  $MgO$  is assumed to be unhydrated.

The test method developed by the Bureau involves the forced hydration of the unhydrated  $MgO$  by high-

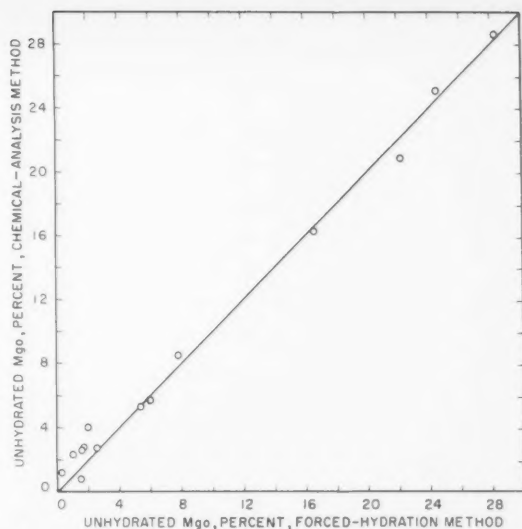
pressure steam in an autoclave. Each water molecule that the lime acquires during autoclaving results from the hydration of 1 molecule of free oxide. If the same assumption is made as in the standard chemical analysis method, namely, that the CaO is already completely hydrated, only the free MgO can be responsible for the gain in water. By determining this gain, the amount of free MgO can be easily derived.

To ascertain the water increment, the lime must be dried before and after hydration to the same degree of dryness. In addition, carbonation must be carefully avoided, since a weight gain due to carbon dioxide would lead to serious error. A CO<sub>2</sub>-free drying apparatus of simple design was therefore developed. It consists of a small desiccator placed in an oven maintained at 120° C. A hole in the desiccator cover is fitted with a two-holed rubber stopper. Compressed air is taken in through a reducing valve and passed through a train, consisting of a gas washing bottle containing concentrated sulfuric acid and a drying tower containing Ascarite and magnesium perchlorate. The dry CO<sub>2</sub>-free air then passes through copper tubing into the desiccator, through one of the holes in the rubber stopper. The desiccator is vented through the other hole. Copper tubing coiled within the oven provides flexibility and easy manipulation of the apparatus.

The sample being investigated is dried in this apparatus, cooled, and weighed. It is then placed in an autoclave and subjected to saturated steam at a pres-



Carbon dioxide-free drying apparatus used for drying lime. A small desiccator is placed in an oven maintained at 120° C. Dry CO<sub>2</sub>-free air under slight pressure is passed through a coil of soft copper tubing into the desiccator through one hole in the rubber stopper and is vented through the other hole. The coiled copper tubing provides flexibility and easy manipulation of the apparatus inside the oven. This type of drying allows a precise gravimetric determination of the gain in water during the forced hydration of the lime. The amount of water gained is a measure of the amount of free magnesia in the lime samples.



Relation between percentage of unhydrated MgO in dolomitic lime hydrate obtained by two methods. The diagonal line illustrates the equality of results obtained by rapid forced hydration and chemical analysis. There is no significant difference between the unhydrated MgO values obtained by the two methods.

sure of 295 lb./in.<sup>2</sup> for 1 hour. After a second drying it is cooled and weighed again. The increase in weight, which is the difference between the oven-dry weights before and after autoclaving, is assumed to be due entirely to the gain in water, and is multiplied by a conversion factor to obtain the weight of free MgO in the sample.

Duplicate tests were made by the forced-hydration method on 14 hydrated dolomitic lime samples. Comparative data were also obtained on the unhydrated MgO content of the same limes by the standard chemical-analysis method. No significant difference was noted between the free MgO values obtained by the two methods. However, the results obtained by the forced hydration method were reproducible with considerably greater precision than those obtained by the standard chemical-analysis method.

<sup>1</sup> A new and rapid method for determining unhydrated magnesia in dolomitic lime hydrates, by E. Trattner, *ASTM Bul.* 225, p. 53 (1957).

<sup>2</sup> Expansive characteristics of hydrated limes, *NBS Tech. News Bul.* 32, 105 (September 1948); Plaster failures resolved, *NBS Tech. News Bul.* 35, 74 (May 1951); Aging of lime putties, *NBS Tech. News Bul.* 36, 139 (September 1952).

For further technical details, see also Hydration of magnesia in dolomitic limes and putties, by L. S. Wells and K. Taylor, *J. Research NBS* 19, 215 (1937) RP1022; Expansive characteristics of hydrated limes and the development of an autoclave test for soundness, by L. S. Wells, W. F. Clarke, and E. M. Levin, *J. Research NBS* 41, 179 (1948) RP1917; Investigation of failures of white-coat plaster, by L. S. Wells, W. F. Clarke, E. S. Newman, and D. L. Bishop, *BMS Report* 121 (February 1951).

## Awards of Postdoctoral Resident Research Associateships

**E**IGHT outstanding young scientists have accepted awards as Postdoctoral Resident Research Associates at the National Bureau of Standards. Within the program established 3 years ago under the cooperative sponsorship of the National Academy of Sciences-National Research Council and the Bureau, recipients of these awards will undertake advanced basic study in the fields of their proven competence. Including the new appointees, a total of 20 Associates have participated in this program at the Bureau since 1954.

The new Resident Research Associates either have received or will shortly receive their Ph. D. degrees from leading universities. They are: Robert E. Donadio, Herkimer, N. Y.; Howland A. Fowler, New York, N. Y.; Russell V. Hanks, Tucson, Ariz.; Victor W. Laurie, Columbia, S. C.; Dale M. Mesner, Central City, Neb.; Charles Muckenfuss, Cleveland, Ohio; Martin H. Pearl, New York, N. Y.; and Donald J. Scheiber, Fort Wayne, Ind.

In their applications these men specified the general area of Bureau activity in which they sought to participate. Likewise, they requested particular staff members as advisors in the execution of their projects. Research will be performed under direct supervision of these Bureau scientists, who are recognized specialists in their fields.

Intensified study and research on the postdoctoral level is traditional in Western science. Although the value of such advanced work is unquestioned, appointments offering opportunity for this purpose have decreased in ratio to current scientific expansion. The Postdoctoral Resident Research Associateships, therefore, contribute significantly toward partial fulfillment of a recognized need.

The National Academy of Sciences—National Research Council postdoctoral fellowships and associate-ship programs are designed to provide additional training for creative young scientists who give promise of leadership in fundamental research. This reciprocal purpose is accomplished by several means. Associates in residence at the Bureau, for instance, are encouraged in their acquisition of basic knowledge by surroundings that are opportune for developing new conceptual approaches to scientific methods and laboratory skills. They benefit also from close association with outstanding staff scientists as well as national and international leaders in scientific fields reflecting Bureau interests. While offering the Associates the advantage of its extensive facilities, the Bureau acquires the professional skill of scientists who will return to academic institutions after their postdoctoral tour.

The Postdoctoral Resident Research Associateships were first announced in October 1954. Since the successful inception of the plan under Bureau auspices, Argonne National Laboratory, Naval Research Lab-

oratory, and Oak Ridge National Laboratory have offered similar programs, also in conjunction with the National Academy of Sciences.

In fulfilling its primary function, the Bureau projects its vital concern with the expanding frontiers of science, particularly through basic research on physical standards and constants, the properties of matter, and testing methodology. Bureau activities, embracing diverse areas in physics, mathematics, chemistry, and engineering, offer varied opportunities for postdoctoral study. Evidence of this range in the present program is the wide representation of Research Associates among the Divisions of the Bureau.

With the addition of Experimental and Theoretical Optics, 21 areas of study are now available to applicants for the fourth series of annual awards. These comprise: Pure and applied mathematics, experimental atomic and nuclear physics, experimental thermodynamics, fundamental problems in physical measurement and computer design, interaction of radiation with matter, low temperature physics, mechanics of fluids and solids, molecular structure and spectroscopy, radiological physics, radio wave propagation, solid state physics, statistical mechanics, visual psychophysics, physics and chemistry of polymers, and analytical, inorganic, organic, and physical chemistry.

The research associateship program is directed by Wallace R. Brode, Associate Director of the National Bureau of Standards and Chairman of the Bureau Educational Committee, and Joseph Hilsenrath and David E. Mann of the Bureau staff. Information concerning awards for the coming year may be obtained from the administrative supervisors for the National Research Council: M. H. Trytten, Director of Scientific Personnel, and Claude Lapp, Director of the Fellowship Office.

Announcements of the 1958 program were posted on October 10, 1957. The application period will close January 13, 1958, and applicants will be notified of the awards early in April.

The eight scientists receiving awards for 1957-58 are as follows:

**ROBERT E. DONADIO**, Temple University (Ph. D.). Dr. Donadio proposes to study organo-phosphorus polymers. His advisor will be Leo A. Wall of the Organic and Fibrous Materials Division.

**HOWLAND A. FOWLER**, Brown University (Ph. D.). Dr. Fowler proposes to investigate polarization in electron beams by means of scattering from solids. His advisor will be L. L. Marton, Chief of the Electron Physics Section.

**RUSSELL V. HANKS**, Brown University (Ph. D.). Dr. Hanks proposes to investigate energy exchange between vibrational and translational degrees of freedom in collisions of fast molecules. His advisor will be chosen from the Temperature Physics Section.



VICTOR W. LAURIE, Harvard University (Ph. D.). Dr. Laurie proposes to study the effect of vibration-rotation interaction of structures obtained from rotational spectra. His advisor will be David E. Mann of the Thermodynamics Section.

DALE M. MESNER, Michigan State University (Ph. D.). Dr. Mesner proposes research into new methods for the study of incidence matrices. His advisor will be William S. Connor of the Statistical Engineering Section.

CHARLES MUCKENFUSS, University of Wisconsin (Ph. D.). Dr. Muckenfuss proposes to study the kinetic

theory of nonspherical molecules and the transport of angular momentum. His advisor will be Melville S. Green of the Thermodynamics Section.

MARTIN H. PEARL, University of Wisconsin (Ph. D.). Dr. Pearl proposes research in the field of matrices. His advisor will be Morris Newman of the Applied Mathematics Division.

DONALD J. SCHEIBER, Notre Dame University (Ph. D.). Dr. Scheiber proposes investigation of the low temperature dielectric properties of polymers. His advisor will be John D. Hoffman, Chief of the Dielectrics Section.

## Publications of the National Bureau of Standards

Journal of Research of the National Bureau of Standards, Volume 59, No. 4, October 1957 (RP2792 to RP2800 incl.), 60 cents. Annual subscription \$4.00.

Technical News Bulletin, Volume 41, No. 10, October 1957, 10 cents. Annual subscription \$1.00.

Basic Radio Propagation Predictions for January 1958. Three months in advance. CRPL-D 158. Issued October 1957. 10 cents. Annual subscription \$1.00.

### Research Papers

Journal of Research, Volume 59, No. 4, October 1957. 60 cents.

RP2792. Formulas for inverse osculatory interpolation in the complex plane. Herbert E. Salzer.

RP2793. An X-ray study of textural stresses in two-phase alloys. C. J. Newton and H. C. Vacher.

RP2794. Dissociation of 4-chloro-4'-aminodiphenylsulfone. Elizabeth E. Sager and Fleur C. Byers.

RP2795. Speed of sound in water by a direct method. Martin Greenspan and Carroll E. Tschiegg.

RP2796. Pattern of a flush mounted microwave antenna. James R. Wait.

RP2797. Standards for pH measurements from 60° to 95° C. Vincent E. Bower and Roger G. Bates.

RP2798. A numerical study of Dedekind's cubic class number formula. Harvey Cohn.

RP2799. Impact properties of slack-quenched alloy steels. Melvin R. Meyerson and Samuel J. Rosenberg.

RP2800. Synthesis of C<sup>14</sup>-labeled L-sorbose and L-ascorbic acid. H. L. Frush and H. S. Isbell.

### Circulars

C584. Simulators for use in development of jet engine controls. Emile S. Sherrard. 20 cents.

C586. Electric hygrometers. Arnold Wexler. 20 cents.

### Publications in Other Journals

The impact-absorbing capacity of textile yarns. J. C. Smith, F. L. McCrackin, H. F. Schiefer. Am. Soc. Testing Materials. (American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.) ASTM Bull. 220 (Feb. 1957).

The mode theory of VLF ionospheric propagation for finite ground conductivity. James R. Wait. Proc. I. R. E. (Inst. of Radio Engineers, Inc., 1 E. 79th St., New York 21, N.Y.) 45, No. 6 (June 1957).

Unit-cell data of the lead niobate PbNb<sub>2</sub>O<sub>6</sub>. Robert S. Roth, Acta Cryst. (Einar Munksgaard, Nørregade 6, Copenhagen, K. Den.) 10, Pt. 6, 437 (June 1957).

Note on the dielectric properties of magnesium-strontium titanates. S. Marzullo and E. N. Bunting. J. Am. Ceram. Soc. (4055 N. High St., Columbus 2, Ohio) 40, No. 8, 285-286 (Aug. 1957).

Application of quaternions to the representations of a binary quadratic form as a sum of four squares. G. Pall and O. Taussky. Proc. Roy. Irish Acad. (Hodges, Figgis & Co., Ltd., 6 Dawson St., Dublin, Ireland) Sec. A 58, No. 3 (July 1957).

Basic standards for science and industry—I. R. D. Huntoon. Electronic Design. (Hayden Publishing Co., Inc., 19 E. 62d St., New York 21, N. Y.) 5, No. 12, 38-41 (June 1957).

Basic standards for science and industry—II. R. D. Huntoon. Electronic Design. (Hayden Publishing Co., Inc., 19 E. 62d St., New York 21, N. Y.) 5, No. 16, 38-41 (Aug. 1957).

Development of craze and impact resistance in glazing plastics by multiaxial stretching. G. M. Kline, I. Wolock, B. M. Axilrod, M. A. Sherman, D. A. George, and V. Cohen. Natl. Advisory Comm. Aeronaut. (Hq., 1512 H St. NW., Washington 25, D. C.) Report 1290 (June 1956).

Excess noise in microwave crystal diodes used as rectifiers and harmonic generators. J. M. Richardson and J. J. Faris. IRE Trans. on Microwave Theory Tech. (The Institute of Radio Engineers, 1 E. 79th St., New York 21, N. Y.) MTT-5, No. 3, 208-212 (July 1957).

Electrical properties of BaTiO<sub>3</sub> containing samarium. George G. Harman. Phys. Rev. (The American Inst. of Physics, 57 E. 55th St., New York 22, N. Y.) 106, No. 6, 1358-1359 (June 1957).

Graphical solution of single-degree-of-freedom vibration problem with arbitrary damping and restoring forces. W. H. Pell. J. Appl. Mechanics. (American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N. Y.) 24, No. 2, 311-312 (June 1957).

Mechanized computation of thermodynamic tables at the National Bureau of Standards. Joseph Hilsenrath and Joseph H. Wegstein. Proc. Inst. Mech. Engrs. (London). Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster SW1, Eng.) Paper 3 (July 1957).

Thermodynamic properties at high temperatures. Charles W. Beckett and Lester Haar. Pro. Inst. Mech. Engrs. (London). (Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster SW1, Eng.) Paper 4 (July 1957).

Noise investigation at VLF by the National Bureau of Standards. William O. Crichlow. Proc. IRE (Inst. of Radio Engineers, Inc., 1 E. 79th St., New York 21, N. Y.) 45, No. 6, 778-782 (June 1957).

On the atmospheric dynamo theory. Marvin L. White. J. Geophys. Research. (Editorial Office, 5241 Broad Branch Rd. NW., Washington 15, D. C.) 62, 329-330 (1957).

Spectroscopic survey of energy distributions of OH, C<sub>2</sub>, and CH radicals in low pressure acetylene-oxygen flames. Herbert P. Broida and Donald F. Heath. J. Chem. Phys. (American Inst. of Physics, Inc., 57 E. 55th St., New York 22, N. Y.) 26, No. 2, 223-229 (Feb. 1957).

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- Systems of inequalities involving convex functions. Ky Fan, Irving Glicksberg, A. J. Hoffman. *Proc. Am. Math. Soc.* (The American Mathematical Society, 80 Waterman St., Providence 6, R. I.) **8**, No. 3, 617-622 (June 1957).
- The analysis of incomplete block designs. Marvin Zelen. *J. Am. Stat. Assoc.* (1108 16th St. NW., Washington 6, D. C.) **52**, 204-217 (June 1957).
- The condenser microphone as a displacement detector calibrator. Walter Koidan. *J. Acoust. Soc. Am.* (American Inst. of Physics, Prince and Lemon Sts., Lancaster, Pa.) **29**, No. 7, 813-816 (July 1957).
- The effect of prism on the location of the principal point. Francis E. Washer. *Photogrammetric Eng.* (American Society of Photogrammetry, Box 18, Benjamin Franklin Sta., Washington, D. C.) **23**, No. 3, 520-532 (June 1957).
- The effect of weathering on certain mortars exposed in brick masonry with and without caps and flashings. J. W. McBurney. *Proc. Am. Soc. Testing Materials*. (American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.) **56** (1956).
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- Sur l'utilisation des observations météorologiques courantes en propagation radioélectrique. B. R. Bean. *L'Onde Électrique*. (Society of Radio Electricians, 10 Avenue Pierre-larrouse, Malakoff (Seine), Paris, France.) **37**, No. 362, 411-415 (May 1957).

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- The waveguide mode theory of the propagation of very-low-frequency radio waves. K. G. Budden. *Proc. IRE* (Inst. of Radio Engineers, Inc., 1 E. 79th St., New York 21, N. Y.) **45**, 772-777 (June 1957).
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- Survey of geomagnetic eclipse phenomena. S. Chapman. *Special Supplement. J. Atm. and Terrest. Phys.* (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.) **6**, 221-227 (1956).
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